The Perils of Human Activity: Lessons from Colombia's Experience with Soil Erosion

by Juan D. Restrepo

RIVER SYSTEMS ARE the primary agents of erosion, transportation, and deposition in most landscapes. Transfer of sediment by rivers is a key component of the global denudation system and provides a general measure of the rate of denudation of the continents and of the efficacy of erosion processes in lowering the land surface of the globe. In other words, sediments transported by rivers are the firsthand indication of how the landscape is evolving. Also, an important proportion of the sediment transported by many of the world's rivers represents soil eroded from mining and deforested and agricultural lands. Deviations from the ambient sediment flux therefore provide a measure of land degradation and the associated reduction in the global soil resource.

It is well documented that human-induced factors and natural influences, such as climate and river runoff, and many characteristics of the drainage basin, including size, geology, morphology, and vegetation, control the "normal" transport of sediment along hydrological pathways. Rivers and their watersheds are Earth systems that evolve across time, with modern river dynamics mostly influenced both by paleo conditions within the drainage basin and by perturbations of humans. Variability in fluxes of water and sediment from rivers reflects the influence of both long-term (century to millennial) and short-term (annual and interannual) fluctuations in climate. Superimposed on these influences are the effects of human-induced change on both the drainage basin and the river itself (Restrepo and Syvitski 2006).

Many authors have documented the relevant role played by so-called technological denudation, the human contribution to sediment generation. A good discussion on the human role in recent landscape change is given by Bonachea et al. (2010). According to these authors, human mobilization of sediments could be one or two orders of magnitude greater than denudation/transport by natural processes. In fact, global erosion rates from natural processes are between 0.1 and 0.01 mm yr^{-1}, while land loss due to human activities accounts for 1 mm yr^{-1} (e.g., Rivas et al. 2006; Syvitski et al. 2005). There is no doubt that human impact on land surface is one of the main drivers of global change. Human capability to alter soils, land erosion, and sediment transport in rivers triggers a geomorphic response in the form of increased rates of natural disasters such as landslides and floods, and produces other associated environmental changes like

soil denudation, desertification, habitat loss, and sedimentation. According to this global picture of human intervention on the territory, a relevant and unsolved issue in the Andean region as well as in other world river catchments is whether land-use change or climate change is the main trigger of accelerated erosion-accumulation processes and related extreme events (e.g., floods and landslides).

Similar to other rivers worldwide, the northern Andean rivers of Colombia are experiencing environmental consequences due to soil degradation, including increased sediment production; reduced soil resilience to erosion; mass movements (landslides); sediment deposition in rivers, lakes, wetlands, and coastal zones; reduced hydrologic storage in water bodies; and increasing frequency and magnitude of floods.

During La Niña event 2010–2011, Colombia and its larger Andean river, the Magdalena, experienced the worst flooding event on record, called the "wet wave." Economic losses were almost US$15 billion (3% of the national GDP), twice the economic losses as those of the last major earthquake in the coffee region in 1999. Environmental institutions, including the Ministry of Environment and Sustainable Development, the National Environmental System (SINA), the regional corporations, and the central government, are blaming climate change as the major trigger of the "wet wave." In the last decade, scientific studies by the Universidad EAFIT of the Andean rivers of Colombia formulate a different hypothesis. They suggest that there is an increase in the rate and magnitude of natural disasters associated with soils (floods, landslides) that could be due mainly to growing land-surface modification caused by human activity, and to a lesser extent, by climate change. If this hypothesis is proved for the Andean region, it could have a major impact on mitigation strategies, since funds could be directed towards soil conservation rather than climate change mitigation. The first approach has a regional impact, and its results are more measurable at local and regional scales, while the second is a global issue that depends on developed countries and economies.

A RELEVANT AND UNSOLVED ISSUE IN THE ANDEAN REGION AS IN OTHER WORLD RIVER CATCHMENTS IS WHETHER LAND-USE CHANGE OR CLIMATE CHANGE IS THE MAIN TRIGGER

One of the first studies assessing the human impact on soil erosion in Colombia (Restrepo and Syvitski 2006) shows that erosion for the whole central part of the northern Andes can be explained by natural variables, including runoff and maximum water discharge. These two estimators explain 58% of variance in erosion. Temporal analyses of sediment discharges and land use show that the extent of erosion within the Colombian catchments has increased over the last 10 to 20 years. Many anthropogenic influences, including a forest decrease by 44% in a 20-year period, an agriculture and pasture increase by 75%, poor soil conservation and mining practices, and increasing rates of urbanization, may have accounted for the overall increasing trends in erosion on a regional scale.

The percentage of forest cover in the Andes of Colombia was estimated to have declined from 66% in 1970 to 22% in 1990, with an annual deforestation rate of 1.9%, or 274,000 ha yr^{-1} (Restrepo and Syvitski 2006). For the whole country, a recent assessment of deforestation by IDEAM (National Institute of Hydrology and Environmental Studies) between 2000 and 2008 indicates a national rate of forest loss of 336,000 ha yr^{-1}. This rate is considered to be among the highest in the world. For instance, when comparing this rate of deforestation to the global rates published by FAO (2010), Colombia, with an area of 1.14 million km^2 and representing about 0.1% of the global land, contributes with approximately 5% to the global forest loss. According to the recent study on numerical modeling of erosion in the northern Andes by Universidad EAFIT and the University of Colorado at Boulder (Kettner et al. 2010), human activities in terms of deforestation explain about 32% of the observed variance in erosion! Thus, the amount of sediment transported by Andean rivers of Colombia to the Caribbean Sea, approximately 50 Mt (million tons) annually, is due to deforestation.

The illicit drug trade of coca in Colombia, Peru, and Bolivia also has been identified as a contributor to deforestation in the tropical Andes (Harden 2006). The U.S. State Department (2001) estimated that a minimum of 2.4 Mha (million hectares) of forest was cleared for coca production in the Andean region over the previous 20 years. The environmental report of Colombia, a study made by the World Bank (Sánchez-Triana et al. 2007), estimated that at least 850,000 ha of forest were also cleared for coca production in the Colombian Andes between 1978 and 1998. A recent survey in the Pacific forests of Colombia, including the Patía River drainage basin, has shown a dramatic expansion of the area of deforestation due to cocaine crops. In the Patía River catchment alone, including a major tributary system, the Telembí River, approximately 12,000 ha of forest were cleared for cocaine crops since the mid-1990s. This is the largest area of cocaine cultivation in the country. Overall, one-third of the deforested area in Colombia is due to cocaine crops (Report of United Nations Office Against Drugs 2011).

Agriculture plays a major role in the dynamics of landscape fragmentation. As in other tropical highland regions, agricultural intensification has been documented in the northern Andes of Colombia. Since 1985 the participation of agricultural activities in the gross domestic product has increased five-fold. It includes, with more or less equal frequencies, forest conversion for permanent cropping, cattle ranching, shifting cultivation, and colonization agriculture. According to Geist and Lambin (2002), agricultural expansion is by far the leading land use change associated with nearly all deforestation cases in tropical regions (96%). Also, this study on proximate causes and underlying drivers of tropical deforestation points out that permanent agriculture displays low geographical variation in tropical areas; that is, regional values for permanent cultivation in Latin America, for example, are close to the global value (i.e., 50%). For the Andes of Colombia, the results presented by Restrepo and Syvitski (2006) and

previous evidence from other assessments of land cover change in Colombia suggest that forest loss and expansion of agricultural land are directly correlated. In addition, an estimate of the Republic Bank of Colombia shows that land for cattle ranching increased from 16 Mha in 1984 to 66 Mha in 2008.

Although agriculture may be the dominant cause of catchment disturbance and accelerated erosion in most areas of the world, other forms of land disturbance, including logging and mining, can also have a significant impact on sediment mobilization and increase specific erosion from small basins by as much as 20-fold. For the central Andes of Colombia, mining activities have increased their participation in the gross domestic product by approximately 70% during the last 15 years. Within the Magdalena River, the Cauca basin shows a dramatic increase in sediment transport for the last 20 years. The most extensive and profitable gold mining is located in the lower course of the Cauca and its tributary, the Nechi. Gold extraction has increased from 6.6 T/yr of gold in 1990 to 25 T/yr in 2008. Associated high concentrations of suspended sediments, often greater than 1,600 mg l^{-1}, have resulted from the rapid erosion of the lowlands, partly because of ongoing gold mining.

Currently, Colombia is having a huge debate about the relationship between economic growth and mining activities. Many environmental issues are discussed in the media, including how multinational mining companies are acquiring land, soil, and resources. Environmentalists argue that increased economic growth by consuming natural resources is one of the main drivers of environmental deterioration. The Colombian government is providing tax incentives to multinational companies to come and explore the territory. This is how the government plans to increase the national GDP in the short term. The income obtained from mining companies in 2011, including oil industries, was $6.53 billion, but the government gave back to these companies $3.51 billion in tax exemptions. It is well known that mining is the first driver of deforestation in the Andes and in the Amazon regions of Colombia since 2000. Furthermore, illegal mining has increased exponentially between 2004 and 2012. Between 2004 and 2008, the government issued licenses to mining companies for 10% of the Colombian territory. For example, the total number of mining licenses issued to companies in 2004 was about 1,047. By 2008 that number increased to 8,444. Right now some assessments indicate that near 60% of the Colombian territory is being negotiated for mining by multinationals.

All environmental facts mentioned above indicate that land use in the Andes of Colombia during the last four decades has altered river hydrology and soils, which in turn have produced geomorphic responses in the upstream and river floodplains. The observed magnitude of floods during the so-called wet

Sediments from gold mining emptying into the Cauca River, the main tributary system of the Magdalena River, Colombia.

wave in 2010–2011 appear to be due to the increasing trend of erosion and further sediment deposition in rivers, lakes, and wetlands, a process that has reduced hydrologic storage of these water bodies and has increased the frequency and magnitude of floods.

In Colombia, deniers of land-use change and its impact on floods argue that climate change is the main trigger of the experienced floods during the last four years. Nevertheless, the following arguments at a global and regional scale, based on reports and models by the IPCC (International Panel of Climate Change) and regional studies, allow us to rule out changes in precipitation as the main cause: (1) only 2%–7% of the global analyzed time series of precipitation show increasing trends; (2) the observed exponential increasing trend of global floods does not match with trends in precipitation at any geographical scale; (3) there is no proven scientific connection between the occurrence of La Niña events and climate change; (4) there are no reliable predictions of precipitation trends in Latin America; (5) a recent study on precipitation trends in Colombia during the last three decades (Cardona and Poveda 2011) shows no regional sign of increasing trend in rainfall; and (6) Andean rivers of Colombia exhibit increasing trends in sediment transport and water discharge, while no trend in rainfall. Thus, it appears that rivers are having more water in their channels for the same amount of precipitation received in their catchments (Restrepo 2005).

If the working hypothesis were correct, that is, that humans are the main cause of erosion and recurrent floods, this finding would have important consequences for mitigation and adaptation. Thus, the institutional policies should also consider land-use change due to human activities in addition to climate change. The latter depends on international policies, while the former is easier to address at local and regional scales.

James Hansen, a well-known climate scientist, affirms: "Our current challenge in environmental science relates to how research should be communicated to the public and policy makers." A social process designed to bring the findings of science to bear on the needs of decision-makers should rely on scientific assessments. The judgment of experts to existing knowledge provides scientifically credible answers to policy relevant questions. In Latin America and the Caribbean, a region that seeks to balance economic growth with environmental sustainability, the connection between science and decision-makers is the missing piece of the environmental puzzle. Government institutions are not well informed about the kind of science accomplished in many disciplines, and scientific results are not incorporated within future development planning and mitigation strategies against natural disasters. Sybil Seitzinger, the Executive Director of IGBP (International Geosphere Biosphere Program), says: "What is needed is a science-policy interface that connects the dots, proposes solutions and sounds alarm bells on emerging issues." This is the part that governments in developing countries, including Colombia, are omitting: the communication between environmental scientists and policy makers.

Imagine a country like Colombia, located in the Intertropical Convergent Zone within the humid tropics, full of biological productivity and biodiversity (second only to Brazil with more biodiversity per square meter), and sixth top country in water resources. With all these geographic conditions it is hard to conceive that this could be a land similar to Haiti. In fact, Colombia is rapidly headed in that direction. The same situation occurs in many Latin American and Caribbean countries. Thus, the way to approach this socioeconomic and environmental challenge is to develop capacity building to assess the effects of human activities in our territories, reviewing the way to value and include ecosystem services into the economies. In other words, we need to get rid of the climate change speech and focus on the way we treat our land. ✸

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